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SOIL-VEGETATION CORRELATIONS WITHIN THE RIPARIAN ZONE OF BUTTE SINK IN THE SACRAMENTO VALLEY OF NORTHERN CALIFORNIA

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SOIL-VEGETATION CORRELATIONS WITHIN THE RIPARIAN ZONE OF BUTTE SINK IN THE SACRAMENTO VALLEY OF NORTHERN CALIFORNIA

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PREFACE

The National Ecology Research Center of the U.S. Fish and Wildlife Service (FWS) is supporting a series of field research studies to document relationships between hydric soils and wetland vegetation in selected wetlands throughout the United States. This study is one of that series. It is a continuation of the FWS effort, begun by Wentworth and Johnson (1986), to develop a procedure using vegetation to designate wetlands based on the indicator status of wetland vegetation as described by the FWS "National List of Plants that Occur in Wetlands" (Reed 1986). This list classifies all vascular plants of the U.S. into one of five categories according to their natural frequency of occurrence in wetlands. Concurrent with the development of the wetland plant list, the Soil Conservation Service (SCS) developed the "National List of Hydric Soils" (SCS 1985). Studies supported by the National Ecology Research Center quantitatively compare associations of plant species, designated according to their hydric nature using the Wentworth and Johnson (1986) procedure, with the hydric nature of soils according to their designation on the SCS hydric soils list. The studies are being conducted across moisture gradients at a variety of wetland sites throughout the U.S. Several studies have been modified to obtain concomitant information on groundwater hydrology.

These studies were conceived in 1984 and implemented in 1985 in response to internal planning efforts of the FWS. They parallel, to some extent, ongoing efforts by the SCS to delineate wetlands for Section 1221 of the Food Security Act of 1984 (the swampbuster provision). The SCS and FWS provided joint guidance and direction in the development of the Wentworth and Johnson (1986) procedure, and the SCS is currently testing a procedure that combines hydric soils and the Wentworth and Johnson procedure for practical wetland delineation. The efforts of both agencies are complimentary and are being conducted in close cooperation.

The primary objectives of these studies are to (1) assemble a quantitative data base of wetland plant community dominance and codominance for determining the relationship between wetland plants and hydric soils; (2) test various delineation algorithms based on the indicator status of plants against independent measures of hydric character, primarily hydric soils; and (3) test, in some instances, the correlation with groundwater hydrology. The results of these studies also can be used, with little or no supplementary hydrologic information, to compare wetland delineation methods of the Corps of Engineers (1987) and the Environmental Protection Agency (Sipple 1987).

Any questions or suggestions regarding these studies should be directed to: Charles Segelquist, 2627 Redwing Road, Creekside One Building, Fort Collins, Colorado 80526-2899, phone FTS 323-5384 or Commercial (303) 226-9384.

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INTRODUCTION

Riparian systems (the vegetation and associated animal life found in close proximity to streams and other water courses, around lakes, and adjacent to springs, seeps, and desert oases) are perhaps the most important of all ecosystems to fish and wildlife. They also improve the health of associated aquatic environments by enhancing erosion control and improving water quality. Riparian vegetation is the source of nutrients for streams, and it also offers diverse recreational opportunities (Warner 1979). The high value of wetland habitats has been recognized by biologists and land planners for decades; however, in the last 150 years America has destroyed between 70 and 90 percent of her indigenous riparian resources and badly damaged much of the rest (U.S. Council on Environmental Quality 1978). In response to the obvious need for greater protection for the remaining wetland environments, governmental agencies have actively moved to conserve riparian ecosystems through legislation and educational programs.

The successful operation of any program to conserve wetlands requires first, a widely accepted definition of what constitutes a wetland, and, second an accurate and easily used methodology for identifying and mapping the boundaries of existing wetland habitats.

The U.S. Fish and Wildlife Service (Cowardin 1979), the Army Corps of Engineers (1987), and Soil Conservation Service (1985) are concerned with wetland classification and the problem of onsite definition of wetland boundaries. Cowardin et al. (1979) define wetland systems on the basis of vegetation, soil, and water regime criteria. Wetlands are lands that are:

> transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For purposes of this classification, wetlands must have one or more of the following three attributes: (1) at least periodically the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year.

Current wetland classification systems rely strongly on the correlation between hydric soils and hydrophytic vegetation. Hydric soils are defined as soils that, in an undrained condition, are saturated, flooded, or inundated long enough during the growing season to develop anaerobic conditions, which favor the growth and regeneration of hydrophytic vegetation (Soil Conservation Service 1985). The U.S. Fish and Wildlife Service (Reed 1986) has compiled lists of wetland or hydrophytic plants indigenous to localized regions of the United States, and the Soil Conservation Service (1985) has compiled a list of wetland or hydric soils. Wentworth and Johnson (1986) have developed

methodologies for delineating wetlands solely by vegetation criteria. In this study, the Wentworth and Johnson approach was applied to map the upland and wetland habitats in the vicinity of Butte Sink, a natural depression within the watershed of the Sacramento River in northern California. The purpose of this study was to determine the degree of correlation that occurs between the distribution of wetland plants as listed by Reed (1986) and hydric soils as described by the Soil Conservation Service (1985).

DESCRIPTION OF THE STUDY AREA

This study was carried out within wetlands and adjacent more well drained sites in the Butte Sink region of Sutter County, California (Figure 1). Historically, natural levees and naturally occurring flood basins prevented some streams draining from the Sierra Nevada from reaching the main rivers. Instead, these streams spread out "through a welter of distributaries" (Thompson 1961) on the Sacramento River valley floor. These distributaries typically ended in "sinks" of tule marsh. Butte Creek exemplifies this pattern and historically never joined the main Sacramento River drainage network. The low-lying lands to the east of Butte Creek (elevation 45-60 feet above sea level) flooded each winter, and the soils remained saturated until late spring or early summer. The natural riparian vegetation occupying this area was largely removed in the last century, as the area was developed for agriculture. The Arkansas Act of 1850 gave the State of California millions of acres of Federally owned floodplains, provided that the State drain and reclaim these lands. The act stipulated that all manmade levees were to be constructed along natural drainage systems. However, the Green Act of 1868, passed by the California Legislature, allowed landowners to construct levees for their own convenience, with little or no regard to the natural or hydrologic systems, and today large portions of the southern half of Butte Sink are still in cultivation (Kahrl 1979). Conversion to cropland required that the natural flooding cycle of Butte Creek be controlled and regulated to provide earlier access to cropland, and the annual inundation cycle over much of the sink was effectively altered.

Recently, an increased interest in the reconstitution of native vegetation on low-lying areas within the "sink," in order to provide habitat for waterfowl migrating along the Pacific Flyway, has caused much of the northern half of Butte Sink to be converted from agriculture back to native wetland vegetation. These reconstituted wetlands are largely managed as hunting clubs, and the existing system of levees and canals allows for some manipulation of the water table during the growing season to control undesirable weeds and to allow for the formation of ponds in the fall to increase the attractiveness of the sites for migratory waterfowl.

Hydric soils in the Butte Sink region that are still used for agriculture may no longer experience frequent flooding. However, these soils obtained their hydric soil designations because soil surveyors postulated that in their undrained condition, they would be saturated, flooded or ponded long enough during the growing season to develop anaerobic conditions favoring the growth and regeneration of hydrophytic vegetation. For the most part, the physiognomy of the reconstituted wetland vegetation on duck club lands belies its

Figure 1. Soil series and vegetation study sites at Butte Sink, Sutter County, California. (Legend on next page.)

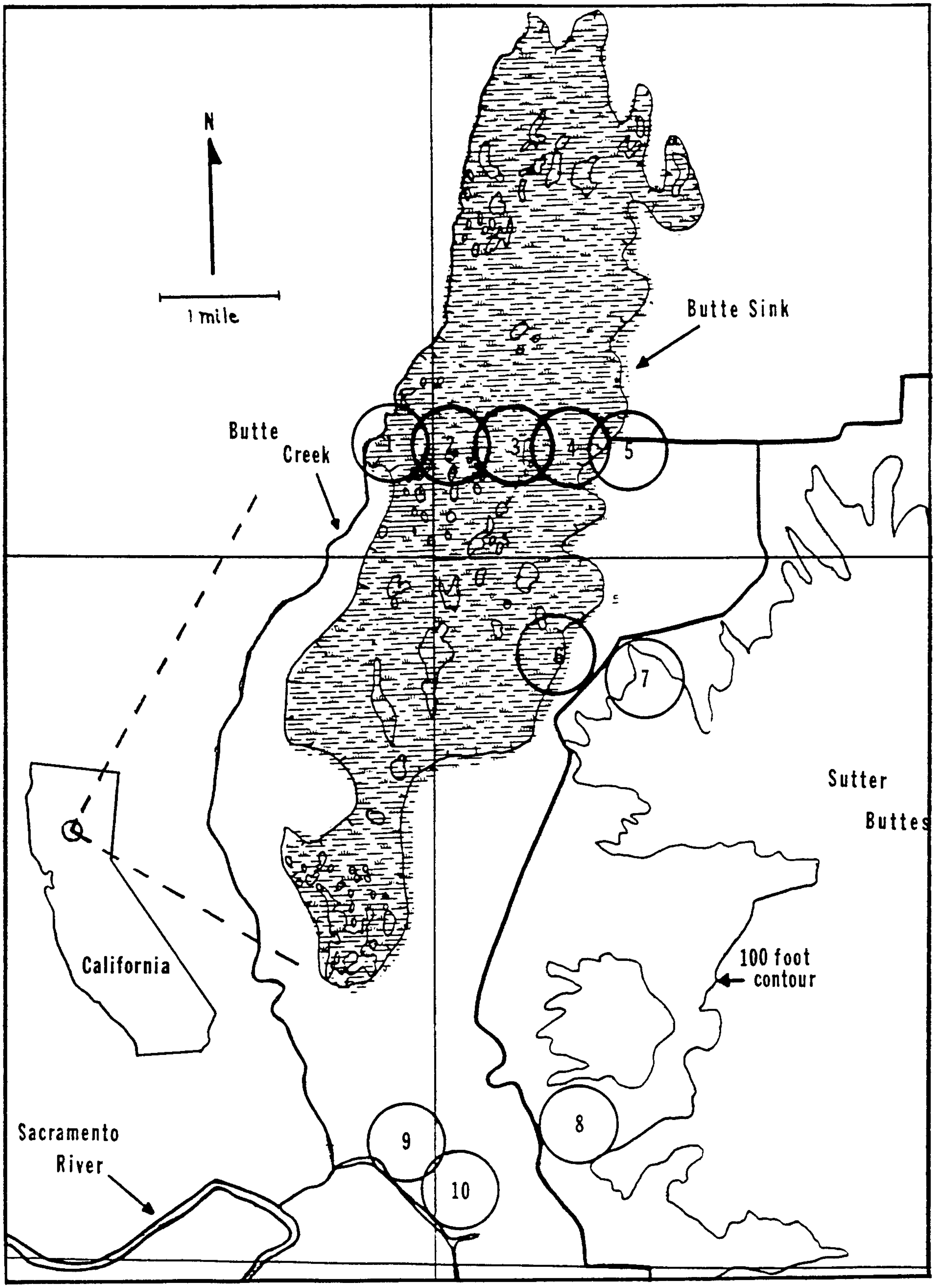

Figure 1. Soil series and vegetation study sites at Butte Sink, Sutter County, California.

1. Capay silty clay (frequently flooded)
2. Clear Lake Clay (drained flooded)
3. Clear Lake Clay (siltstone substratum)
4. Galt clay (flooded)
5. Live Oak variant-Galt variant complex (flooded)
6. Olashes sandy loam (flooded)
7. Palls-Stohlman stony sandy loam (well drained)
8. Olashes sandy loam (well drained)
9. Shanghai silt loam
10. Columbia fine sandy loam

relatively recent origin, and apart from the system of levees insuring the continued hydric nature of the area, these riparian habitats appear natural to the casual observer. Randall Gray of the Soil Conservation Service (1979) surveyed the wetland vegetation of the Colusa Basin-Butte Sink region using color aerial photography. Although no attempt was made to correlate wetland vegetation with the occurrence of hydric soils, the study provided an important baseline data source for monitoring long term changes in the vegetational composition of the area's wetlands.

METHODS

The choice of the Butte Sink region as a location for this study was predicated on the existence of a recent soil survey for Sutter County. Although suitable wetland habitats occurred within easily accessible wildlife refuge holdings in adjacent counties to the north and west of the study area, recent soil surveys were lacking for these sites. This logistical constraint served to require that all data for this study be taken from wetlands and adjacent upland soils owned by privately administered duck clubs, ranches, or farms in Sutter County. The cooperation of these parties was essential for the data collection process and much appreciated (see acknowledgments). In consultation with local Soil Conservation Service personnel and U.S. Fish and Wildlife Service biologists, ten soils were selected, representing eight hydric and two upland soils (Figure 1). Five of the hydric soils were located along a topographically defined moisture gradient stretching from the eastern edge of Butte Creek toward the western edge of the Sutter Buttes, a volcanic plug rising 2100 feet above the surrounding valley floor.

Field work was conducted between 15 July and 21 August 1987. Sampling sites were located randomly in zones of relatively homogeneous vegetation within each soil series. Vegetation in the study plots was classified into four strata within a given soil series: trees, tall shrubs, short shrubs and ground cover layers (Table 1). Only one soil series provided woody vegetation and thus, in the absence of comparable data for all strata, the comparative analysis was confined to the herbaceous ground cover stratum. Northwestern corners of twenty 100 m^2 study plots representing 5 sampling replications per soil series were located at random within each mapped soil unit and placed to provide no less than ten meter spacing between adjacent plots. Within each soil series, forty .5 m^2 rectangular quadrats were established to sample the ground cover stratum. For most mapped soil units, within soil variability was minimized by selecting plots from tracts of relatively homogenous vegetation. In three cases, however (Clear Lake clay, Clear Lake clay - siltstone substratum, and Live Oak variant - Galt variant complex), well defined patterns of vegetational heterogeneity were apparent and plot locations were stratified into two groups of twenty plots each to proportionately reflect these patterns. Tables 4, 5, and 6 summarize ecological index statistics calculated for each of the mapped soil units. For purposes of this report, data from each of the three aforementioned soil units were subdivided and analyzed as two distinct groups of twenty rather than forty .5 m^2 sample plots. This splitting of the data set significantly reduced internal variance by at least a factor of three and allowed for the separate analysis of the effects of

microtopographical differences and differing management practices on vegetational composition.

Table 1. Sampling schemes for vegetation strata.

Strata and definition	Variables measured	Size of quadrats	Replications per soil series
Trees: all stems $\geq$7.5 cm dbh	Density: dbh (cm) all stems	100 m^2	5
Tall shrubs: woody species <7.5 cm dbh, $\geq$1.3 m tall	Density: count all main leaders	4 m^2	5
Short shrubs: woody species <1.3 m, $\geq$0.5 m	Density: count all individual plants emerging from ground	4 m^2	5
Ground cover: woody species <0.5 m and all herbaceous species regardless of height	percent cover in 1-6 Daubenmire (1968) classes[a]	0.5 m^2	10

[a]Daubenmire classes are listed in Table 3.

Plant species occurring within plots were assigned ecological indices from the California List of Wetland Plants (Reed 1986) based on their frequencies of occurrence in wetlands (Table 2). However, in the case of valley oak (Quercus lobata), we chose to lower the ecological index value of this species from 4 to 3 based on our studies of this species' reproductive success along moisture gradients in the Northern Central Valley of California (Knudsen, M.D., Department of Biological Sciences, California State University, Sacramento; unpubl. MS.) Plants not listed by Reed were assigned indices that seemed most appropriate based on our knowledge of each species' relative abundance, and position along the moisture gradient (Appendix B). Most taxa unlisted by Reed were upland species and received an index of 5.

Table 2. Ecological indices used for weighted, presence/absence, and Michener averages, with definitions of modifiers in the Wetland Plant List, California Region.

Modifier	Ecological indices[a] W_j	P_j	M_j	Definition
Obligate	1	1	1	Species always occurring in wetlands (frequency >99%)
Facultative wet and fac. wet drawdown[b]	2	2	.82	Species usually occurring in wetlands (67%-99% frequency)
Facultative and fac. drawdown	3	3	.50	Species sometimes occurring in wetlands (34%-66% frequency)
Facultative upland and fac. upland drawdown	4	4	.18	Species seldom occurring in wetlands (1%-33% frequency)
Upland and upland drawdown	5	5	0	Species occurring in wetlands with less than 1% frequency; also includes all species not assigned one of the above modifiers.

[a]W_j = weighted average (Wentworth and Johnson 1986)
P_j = presence/absence average
M_j = Michener average (Michener 1983)
[b]Drawdown: indicates species favored by drawdown conditions

Weighted averages for the ground cover stratum were calculated for each soil series using the following equation, which was adapted from Wentworth and Johnson (1986):

$$W_j = (\sum_{i=1}^{n} I_{ij}E_i) \ / \ (\sum_{i=1} I_{ij})$$

where W_j = weighted average for stand j

I_{ij} = importance value for species i in stand j

E_i = ecological index for species i

n = number of species in stand j

Importance values were estimates of Daubenmire's (1968) canopy coverage classes as defined in Table 3. The ecological index for each species corresponded to the values derived by Reed (1986) and recorded in the California Wetland Plant List (Table 2 and Appendix B).

Table 3. Importance values assigned to ground cover stratum (Daubenmire 1968).

Importance value	Definition
1	Percent ground cover of 0.1-5
2	Percent ground cover of 6-25
3	Percent ground cover of 26-50
4	Percent ground cover of 51-75
5	Percent ground cover of 76-95
6	Percent ground cover of 96-100

Mean, standard deviation, standard error of mean and range were calculated for ecological indices of vegetation based on weighted averages, presence/absence averages, and Michener (1983) averages, by soil series and vegetation type within soil series. Averages for soil series were analyzed using analysis of variance and Duncan's multiple range test. Results obtained with all these averaging procedures were compared against hydric soil classifications to determine the relative correspondence of each index with the Soil Conservation Service's list of wetland soils.

Table 4. Mean, variance, standard error of means, and range for weighted averages by soil series and habitat.

Soil series and habitat	n (number of plots)	Mean	Variance	Standard error of mean	Range[a]
1. Capay silty clay (frequently flooded)	40	2.15	0.758	0.138	2.02
2. Clear Lake clay	40	1.92	0.279	0.084	1.88
2a. Clear Lake clay (old field flooded for ten days each June)	20	1.92	0.252	0.112	1.81
2b. Clear Lake clay (Tule marsh--never farmed)	20	1.89	0.279	0.118	1.80
3. Clear Lake Clay--siltstone substratum	40	1.71	0.444	0.105	2.22
3a. Clear Lake clay--silt stone substratum (depressions between mounds)	20	1.21	0.027	0.037	0.48
3b. Clear Lake clay--siltstone substratum (raised areas separating depressions)	20	2.21	0.358	0.134	0.24
4. Galt clay (flooded)	40	2.86	0.189	0.069	1.77
5. Live Oak variant-Galt variant complex	40	3.25	1.447	0.190	2.77
5a. Live Oak variant-Galt variant complex (flooded-upland)	20	4.33	0.096	0.021	1.01
5b. Live Oak variant-Galt variant complex (flooded-swales)	20	2.40	0.126	0.079	2.09
6. Olashes sandy loam (flooded)	40	3.63	0.078	0.044	1.21

(Continued)

Table 4. (Concluded)

Soil series and habitat	n (number of plots)	Mean	Variance	Standard error of mean	Range[a]
7. Palls-Stohlman stony sandy loam (well drained)	40	4.89	0.011	0.017	0.44
8. Olashes sandy loam (well drained	40	4.89	0.022	0.023	0.37
9. Shanghai silt loam (riparian forest)	40	3.34	0.405	0.203	2.35
10. Columbia fine sandy loam	40	3.45	0.230	0.076	2.38

[a]Difference between the highest and lowest value in the sample.

Table 5. Mean, variance, standard error of means, and range for presence/absence averages by soil series and habitat.

Soil series and habitat	n (number of plots)	Mean	Variance	Standard error of mean	Range
1. Capay silty clay (frequently flooded)	40	2.26	0.434	0.104	2.33
2. Clear Lake clay	40	2.16	0.124	0.056	1.13
2a. Clear Lake clay (old field flooded for ten days each June)	20	2.15	0.100	0.071	1.67
2b. Clear Lake clay (Tule marsh--never farmed)	20	2.17	0.095	0.069	1.05
3. Clear Lake clay--siltstone substratum	40	1.88	0.463	0.108	2.20

(Continued)

Table 5. (Concluded)

Soil series and habitat	n (number of plots)	Mean	Variance	Standard error of mean	Range[a]
3a. Clear Lake clay--silt stone substratum (depressions between mounds)	20	1.28	0.022	0.033	0.43
3b. Clear Lake clay--siltstone substratum (raised areas separating depressions)	20	2.48	0.172	0.093	0.75
4. Galt clay (flooded)	40	2.91	0.205	0.072	1.83
5. Live Oak variant-Galt variant complex	40	3.11	0.445	0.105	2.53
5a. Live Oak variant-Galt variant complex (flooded-upland)	20	3.75	0.064	0.014	0.92
5b. Live Oak variant-Galt variant complex (flooded-swales)	20	2.64	0.170	0.092	1.92
6. Olashes sandy loam (flooded)	40	3.76	0.088	0.047	1.00
7. Palls-Stohlman stony sandy loam (well drained)	40	4.63	0.043	0.033	0.67
8. Olashes sandy loam (well drained	40	4.75	0.038	0.031	0.50
9. Shanghai silt loam (riparian forest)	40	3.37	0.293	0.150	2.50
10. Columbia fine sandy loam	40	3.28	0.222	0.074	1.57

[a]Difference between the highest and lowest value in the sample.

Table 6. Means, variance, standard error of means and range for Michener averages by soil series and habitat.

Soil series and habitat	n (number of plots)	Mean	Variance	Standard error of mean	Range [a]
1. Capay silty clay (frequently flooded)	40	0.72	0.048	0.035	0.51
2. Clear Lake clay	40	0.78	0.017	0.021	0.37
2a. Clear Lake clay (old field flooded for ten days each June)	20	0.79	0.016	0.029	0.47
2b. Clear Lake clay (Tule marsh--never farmed)	20	0.79	0.017	0.029	0.44
3. Clear Lake clay--siltstone substratum	40	0.82	0.030	0.027	0.57
3a. Clear Lake clay--silt stone substratum (depressions between mounds)	20	0.95	0.002	0.009	0.15
3b. Clear Lake clay--siltstone substratum (raised areas separating depressions)	20	0.68	0.023	0.034	0.11
4. Galt clay (flooded)	40	0.53	0.014	0.019	0.57
5. Live Oak variant-Galt variant complex	40	0.45	0.098	0.050	0.77
5a. Live Oak variant-Galt variant complex (flooded-upland)	20	0.16	0.006	0.001	0.27
5b. Live Oak variant-Galt variant complex (flooded-swales)	20	0.69	0.012	0.025	0.53

(Continued)

Table 6. (Concluded)

Soil series and habitat	n (number of plots)	Mean	Variance	Standard error of mean	Range[a]
6. Olashes sandy loam (flooded)	40	0.32	0.006	0.012	0.34
7. Palls-Stohlman stony sandy loam (well drained)	40	0.03	0.001	0.004	0.11
8. Olashes sandy loam (well drained	40	0.03	0.001	0.006	0.68
9. Shanghai silt loam (riparian forest)	40	0.41	0.032	0.202	0.79
10. Columbia fine sandy loam	40	0.37	0.020	0.023	0.67

[a]Difference between the highest and lowest value in the sample.

RESULTS

One hundred and twenty-four species of ground cover plants (Appendix B), were found in this study of Butte Sink soils. Tree and shrub strata were found only within the riparian forest habitat occurring on Shanghai silt loam soils; since these data were not comparable with any of the other 12 localities, only ground cover vegetation data were analyzed. Means, standard deviations, standard errors of means, and ranges were calculated for weighted averages, presence/absence averages, and Michener averages for soil series and distinctive vegetation types within each soil series at 10 locations within the Butte Sink area (Tables 4, 5, and 6). Table 7 summarizes the tree and shrub data taken from Shanghai silt loam soil. The average ecological indices calculated for the three woody strata on Shanghai soils appear to chronicle the gradually lowering water table of this site since the land was reclaimed for agriculture. The larger (older) trees reflect the more hydric character of the site prior to the construction of levees in the latter part of the nineteenth century, while the younger shrubs and saplings are more typical of the current more xeric site conditions.

The three averages for ecological indices (weighted, presence/absence, and Michener) calculated for each soil series and, in three cases, separate

vegetation types within soil series were analyzed for the existence of significant differences between soil series and vegetation types using the Duncan multiple range test (Tables 8, 9, and 10 respectively). Letter groupings indicate groups of index values which are not significantly different from one another at the 0.05 probability level. Weighted averages and presence/absence averages of index values less than 3.0 are indicative of wetland or hydric vegetation. Vegetation with a Michener average greater than .50 is also considered hydric by this method. Frequencies of occurrence of plant species were determined for each soil series or vegetation type within soil series (Appendix C).

In all cases indices reflecting the prevalence of hydrophytic vegetation corresponded to the currently flooded hydric soils listed by the Soil Conservation Service for Butte Sink. Three soils originally classified as hydric (Shanghai silt loam, Columbia fine sandy loam, and Olashes sandy loam) flooded in the past but currently drained and protected from lengthy periods of flooding, supported herbaceous vegetation of a more upland character, with weighted and presence/absence indices between 3.3 and 3.7. Michener averages, although based on a different numerical scale, exhibited the same high degree of correspondence with the SCS hydric soils list.

DISCUSSION

Hydrophytic vegetation indices based on weighted and presence/absence averages matched the Hydric Soils List (1985) for six of the nine listed hydric soil series.

In contrast to previously published soil-vegetation correlation studies in this series, such as the Sandhill and Rainwater Basin wetlands of Nebraska (Erickson and Leslie 1987) and the riparian zones of the Gila and San Francisco Rivers of New Mexico (Dick-Peddie et al. 1987), the Butte Sink wetlands represent reconstituted riparian habitat derived from lands previously supporting agriculture. These reestablished wetlands, although occurring on hydric soils, did not uniformly experience saturated soil conditions for extended periods of time while they were used as croplands. An extensive levee system controlled natural runoff and, for as long as 100 years, many of these agricultural lands and the intervening natural vegetation were transformed into functional upland habitats. More recently, as interest in waterfowl management increased, many of these parcels have been artificially flooded by regulating flow through the levee system, returning hydric conditions to hydric soils. In every case where current management practices have returned hydric soil conditions to previously farmed parcels in the Butte Sink study area, the natural vegetation developing on these sites, as reflected by the weighted, presence/absence, or Michener averages, conforms well to the actual hydric nature of the underlying soil series.

Table 7. Mean, variance, standard error of means and range for weighted averages, presence/absence averages, and Michener averages calculated for woody vegetation on Shanghai silt loam.

Strata and definition	n (number of plots)	Mean	Variance	Standard error of mean	Range
Trees: all stems $\geq$7.5 cm dbh					
W_j	16	2.76	0.314	0.140	2.00
P_j	16	2.81	0.355	0.149	2.67
M_j	16	0.56	0.024	0.039	0.61
Tall shrubs: woody species <7.5 cm dbh, $\geq$1.3 m tall					
W_j	19	3.08	0.407	0.146	2.40
P_j	19	3.11	0.244	0.113	2.00
M_j	19	0.50	0.042	0.047	0.66
Short shrubs: woody species <1.3 m, $\geq$0.5 m					
W_j	20	3.42	0.480	0.153	2.39
P_j	20	3.41	0.410	0.143	2.50
M_j	20	0.38	0.044	0.047	0.74

Table 8. Duncan's multiple range tests for weighted averages calculated for soil series or plant communities within soil series.

Grouping[a]	Soil series[b]	Mean	Number of observations
A	3a - *Clear Lake clay (siltstone substratum - depressions between mounds)	1.21	20
B	2b - *Clear Lake clay (tule marsh - never farmed)	1.89	20
B	2a - *Clear Lake clay (old field-flooded for 10 days each June)	1.92	20
BC	1 - *Capay silty clay (frequently flooded)	2.14	40
BC	3b - *Clear Lake clay (siltstone substratum -raised areas)	2.21	20
C	5b - *Live Oak variant-Galt variant complex (swales)	2.40	20
D	4 - *Galt clay (flooded)	2.86	40
E	9 - *Shanghai silt loam (riparian forest)	3.34	40
EF	10 - *Columbia fine sandy loam	3.45	40
F	6 - *Olashes sandy loam (flooded)	3.63	40
G	5a - Live Oak variant-Galt variant complex (upland)	4.33	20
H	8 - Olashes sandy loam (well drained)	4.89	40
H	7 - Palls-Stohlman stony sandy loam (well drained)	4.89	40

[a]Mean values for soil series with the same letter grouping are not statistically different at 0.05 probability level.

[b]Asterisks (*) indicate the soil series is included in the Hydric Soils List (Soil Conservation Service 1985).

Table 9. Duncan's multiple range tests for presence/absence averages calculated for soil series or habitats within soil series.

Grouping[a]	Soil series[b]	Mean	Number of observations
A	3a - *Clear Lake clay (siltstone substratum - depressions between mounds	1.28	20
B	2a - *Clear Lake clay (old field - flooded for 10 days each June)	2.15	20
B	2b - *Clear Lake clay (tule marsh - never farmed)	2.17	20
B	1 - *Capay silty clay (frequently flooded)	2.26	40
C	3b - *Clear Lake clay (siltstone substratum - raised areas)	2.48	20
C	5b - *Live Oak variant-Galt variant complex (swales)	2.64	20
D	4 - *Galt clay (flooded)	2.91	40
E	10 - *Columbia fine sandy loam	3.28	40
E	9 - *Shanghai silt loam (riparian forest)	3.37	40
F	5a - Live Oak variant-Galt variant complex (upland)	3.75	20
F	6 - *Olashes sandy loam (flooded)	3.76	40
G	7 - Palls-Stohlman stony sandy loam (well drained)	4.63	40
G	8 - Olashes sandy loam (well drained)	4.75	40

[a]Mean values for soil series with the same letter grouping are not statistically different at 0.05 probability level.

[b]Asterisks (*) indicate the soil series is included in the Hydric Soils List (Soil Conservation Service 1985).

Table 10. Duncan's multiple range tests for Michener averages calculated for soil series or habitats within soil series.

Grouping[a]	Soil series[b]	Mean	Number of observations
A	3a - *Clear Lake clay (siltstone substratum - depressions between mounds)	0.95	20
B	2b - *Clear Lake clay (tule marsh - never farmed)	0.79	20
B	2a - *Clear Lake clay (old field-flooded for 10 days each June)	0.79	20
C	1 - *Capay silty clay (frequently flooded)	0.71	40
C	5b - *Live Oak variant-Galt variant complex (swales)	0.69	20
C	3b - *Clear Lake clay (siltstone substratum -raised areas)	0.68	20
D	4 - *Galt clay (flooded)	0.53	40
E	9 - *Shanghai silt loam (riparian forest)	0.41	40
EF	10 - *Columbia fine sandy loam	0.37	40
F	6 - *Olashes sandy loam (flooded)	0.32	40
G	5a - Live Oak variant-Galt variant complex (upland)	0.16	20
H	8 - Olashes sandy loam (well drained)	0.03	40
H	7 - Palls-Stohlman stony sandy loam (well drained)	0.03	40

[a]Mean values for soil series with the same letter grouping are not statistically different at 0.05 probability level.

[b]Asterisks (*) indicate the soil series is included in the Hydric Soils List (Soil Conservation Service 1985).

Exceptions occur when currently nonflooded vegetation is sampled and compared with the soil's original hydric listing. Abandoned farmland allowed to revegetate naturally on Columbian fine sandy loam and riparian forest corridors left standing between fields on Shanghai silt loam (both soils listed as hydric by Soil Conservation Service) support herbaceous vegetation averaging between 3 and 4 with both weighted and presence/absence averaging methods. Michener averages also predict an upland character for these current occupants of former wetland habitats. As these soils in their drained state no longer meet hydric soil criteria, this result is not surprising. In contrast, the older woody vegetation occupying the islands of riparian forest on Shanghai silt loam have weighted average values and presence/absence values slightly less than 3.0 reflecting the areas past history of more hydric soil conditions.

The third case of a soil originally classified as hydric currently possessing a preponderance of nonwetland plant species is Olashes sandy loam/ flooded. Although located within the historical high water flood boundary of Butte Creek, prevailing flood control practices all but eliminate the possibility that this soil, although classified as hydric, will again experience hydric soil conditions.

Within the secondarily flooded lands currently managed by duck clubs, the three averaging methods correlated well with existing soil classifications. This methodology was particularly effective for resolving soil differences occurring over a distance of a few meters. Approximately 3 km to the west of Butte Creek, soil sample number 5 (classified as Live Oak variant-Galt Variant Complex) was sampled as two separate plant communities: sedge meadow occupying Live Oak soils on the raised uplands and rabbit foot grass meadow occurring on Galt Soils (listed as hydric) within the intervening swales. All three methods yielded index values that correlated directly with the upland and hydric natures of the two included soils.

Although both weighted averages and presence/absence averages served well to identify underlying hydric soils at Butte Sink, significant differences (0.05 probability level) were apparent between indices generated by these two different methods for specific soils (Table 11). Three factors may contribute to the occurrence of a significant difference between estimates of weighted average means and presence/absence average means for any given soil: the size of the difference between the means, the amount of variability within any set of averages, and the number of observations of the average used to estimate the mean index value for a site. Considering the size of the difference between any two index values, inherent differences in the two calculation methods become critical. Indices based on weighted average calculations use an ocular estimation of a species' areal coverage (the species' importance value) as the weighting factor. Where a few species exhibit a high degree of dominance within plant communities, weighted averages appear to more closely reflect the hydric or xeric nature of the vegetation.

The largest discrepancies between the index values obtained by each of the two methods were observed at site 3B, Clear Lake clay with a siltstone substratum (raised areas), and site 5A, Live Oak variant-Galt variant complex (upland). For both of these soil series or groups, a single species of plant-

-at 3B, Nile pricklegrass (*Crypsis niliaca*), and at 5A, a sedge (*Carex teneraeformis*)--exerted a high degree of dominance on a majority of plots within each soil series. In general, by not reflecting a dominant species' relative importance within a plot, index values based on presence/absence data resulted in statistically significant underestimates of a vegetation sample's hydric or upland nature. Operationally, however, the differences between the two sets of indices were apparently not great enough to effect the usefulness of either method as an indicator of wetland habitat or hydric soil.

The possibility exists that the relative degree of dominance expressed by a plant species may be a function of the seral position of the plant community. Younger or recently disturbed habitats typically exhibit lower species diversities and include species with higher levels of dominance. The history of intensive habitat manipulation within the Butte Sink study area has likely prevented vegetation on hydric soils from achieving equilibrium status. Although probably no undisturbed wetland habitats currently exist in the Sacramento River valley to serve as examples of climax hydric vegetation, it appears that some indication of a habitat's recent history of disturbance should prove useful in assessing the impact that dominance and succession have on both weighted average and presence/absence indices. Table 12 lists the thirteen study sites at Butte Sink and attempts to rank each site based on its inferred history of disturbance. Preliminary evidence appears to indicate that recent disturbance within plant communities may increase the likelihood that wetland vegetation index values obtained by weighted averaging and presence/absence averaging methods will diverge from one another and highlights the importance of dominance as a relevant vegetation parameter.

Table 11. A comparison of weighted averages and presence/absence averages calculated for each soil series or habitat.

Number of observations	grouping	Mean of weighted averages	Soil series	Mean of presence/absence averages	grouping	Paired t statistic
20	A	1.21	3a - Clear Lake clay (siltstone substratum - depressions between mounds)	1.28	A	2.66*
20	B	1.89	2b - Clear Lake clay (tule marsh - never farmed)	2.17	B	3.96*
20	B	1.92	2a - Clear Lake clay (old field-flooded for 10 days each June)	2.15	B	2.41*
40	BC	2.15	1 - Capay silty clay (frequently flooded)	2.26	B	1.61
20	BC	2.21	3b - Clear Lake clay (siltstone substratum -raised areas)	2.48	C	2.80*
20	C	2.40	5b - Live Oak variant-Galt variant complex (swales)	2.64	C	3.14*
40	D	2.86	4 - Galt clay (flooded)	2.91	D	1.01
			PRESUMED WETLAND SOIL BOUNDARY			

(Continued)

Table 11. (Concluded)

Number of observations	grouping	Mean of weighted averages	Soil series	Mean of presence/absence averages	grouping	Paired t statistic
40	E	3.34	9 - Shanghai silt loam (riparian forest)	3.37	E	0.51
40	EF	3.45	10 - Columbia fine sandy loam	3.28	E	2.67*
40	F	3.63	6 - Olashes sandy loam (flooded)	3.76	F	2.76*
20	G	4.33	5a - Live Oak variant-Galt variant complex (upland)	3.75	F	9.89*
40	H	4.89	8 - Olashes sandy loam (well drained)	4.75	G	5.37*
40	H	4.89	7 - Palls-Stohlman stony sandy loam (well drained)	4.63	G	9.81

*indicates paired indices that are significantly different ($\alpha = .05$)

Table 12. Relative degree of disturbance experienced by study sites at Butte Sink, Sutter County, California.

Ranking scale:
1 - little or no disturbance evident
2 - medium disturbance
3 - high level of disturbance

Soil Series and Habitat	Disturbance Ranking	Nature of Inferred Disturbance
1 - Capay silty clay (frequently flooded)	1	subject to fall and winter flooding and spring drawdown
2a - Clear Lake clay (old field--flooded for 10 days each June)	3	previously leveled and farmed; currently subject to fall and winter flooding and spring drawdown; flooded again in June to control *Xanthium*.
2b - Clear Lake clay (tule marsh--never farmed)	1	subject to fall and winter flooding and spring drawdown
3a - Clear Lake clay (siltstone substratum--depressions between mounds)	1	subject to fall and winter flooding and spring drawdown
3b - Clear Lake clay (siltstone substratum--raised areas)	1	subject to fall and winter flooding and spring drawdown
4 - Galt clay (flooded)	1	subject to fall and winter flooding and spring drawdown
5a - Live Oak variant-Galt variant complex (upland)	2	Experiences brief winter flooding and light grazing
5b - Live Oak variant-Galt variant complex (swales)	2	regulated flooding in winter and light grazing
6 - Olashes sandy loam (flooded)	3	ruderal weeds reflecting a history of heavy grazing
7 - Palls-Stohlman stony sandy loam (well drained)	1	light grazing
8 - Olashes sandy loam (well drained)	2	heavy grazing
9 - Shanghai silt loam (riparian forest)	2	forest likely established while natural flooding occurred; herbaceous understory reflects the current more xeric environment
10 - Columbia fine sandy loam	3	early successional community following grading and leveling of areas 2 years previous

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APPENDIX A

DESCRIPTIONS OF SOIL SERIES
(Unpublished Soil Survey for Sutter County California, SCS, 1987)

1. Capay silty clay, frequently flooded. This very deep, moderately well drained soil is in basins. It formed in alluvium derived dominantly from mixed sources. Slope is between 0 and 2 percent. Elevation is between 20 and 50 feet. The average annual precipitation is between 14 and 17 inches. The average annual air temperature is between 60 and 64 degrees F, and the average frost-free season is between 260 and 280 days.

Typically, the surface layer is dark grayish brown silty clay 36 inches thick. The underlying material to a depth of 60 inches or more is brown clay loam. In some areas the soil is clay throughout.

Permeability of this Capay soil is slow. Available water capacity is high. Effective rooting depth is 60 inches or more. The soil is wet between a depth of 48 and 60 inches in December through April. Runoff is very slow, and the hazard of water erosion is slight. The shrink-swell potential is high. This soil is subject to frequent long periods of flooding in December through April.

Most areas of this unit are used for irrigated crops, mainly rice and tomatoes. Among the other crops grown are corn, dry beans, milo, and safflower.

2. Clear Lake clay, drained flooded. This very deep soil is in basins. It formed in alluvium derived dominantly from mixed sources. Under natural conditions, this soil is poorly drained; however, drainage has been improved by the use of open ditches and flood control structures. Slope is between 0 and 2 percent. The native vegetation is mainly tules and water grasses. Elevation is between 20 and 50 feet. The average annual precipitation is between 14 and 17 inches, the average annual air temperature is between 60 and 64 degrees F, and the average frost-free period is between 260 and 280 days.

Typically, the surface layer is dark gray clay 42 inches thick. The underlying material to a depth of 60 inches or more is olive gray clay.

Permeability of this Clear Lake soil is slow. Available water capacity is high. Effective rooting depth is 60 inches or more. The soil is wet between a depth of 36 and 60 inches in December through April. Runoff is very slow and the hazard of water erosion is slight. The shrink-swell potential is

high. This soil is subject to frequent long periods of flooding in December through April.

Most areas of this unit are used for irrigated crops, mainly rice. Among the other crops grown are corn, dry beans, milo, and safflower. Some areas are also used for wildlife habitat.

3. Clear Lake clay, siltstone substratum, flooded. This deep soil is in basins. It formed in alluvium derived dominantly from mixed sources. Under natural conditions, this soil is poorly drained; however, drainage has been improved by the use of open ditches and flood control structures. Slope is between 0 and 2 percent. The native vegetation is mainly tules and watergrasses. Elevation is between 20 and 50 feet. The average annual precipitation is between 14 and 17 inches. The average annual air temperature is between 60 and 64 degrees F, and the average frost-free season is between 260 and 280 days.

Typically, the surface layer is dark gray clay 42 inches thick. The underlying material to a depth of 48 inches is light yellowish brown clay over siltstone. Depth to siltstone ranges from 40 to 60 inches. In some areas, the surface layer is stratified with brownish yellow silty clay and dark gray silty clay.

Permeability of this Clear Lake soil is slow. Available water capacity is moderate to high. Effective rooting depth is 40 to 60 inches. There is a perched wet zone between depths of 36 and 60 inches all year. Runoff is very slow, and the hazard of water erosion is slight. The shrink-swell potential is high. This soil is subject to frequent long periods of flooding from December through April.

4. Galt clay, flooded. This moderately deep, moderately well drained soil is in basins and on basin rims. It formed in alluvium derived dominantly from mixed sources. Slope is between 0 and 2 percent. Elevation is between 10 and 40 feet. The average annual precipitation is between 14 and 17 inches, the average annual air temperature is between 60 and 64 degrees F, and the average frost-free period is between 250 and 280 days.

Typically, the surface layer is grayish brown clay 10 inches thick. The underlying material to a depth of 23 inches is brown clay. The next layer is a strongly cemented hardpan 23 inches thick. The underlying material to a depth of 60 or more inches is pale yellow loam. Depth to hardpan ranges from 20 to 40 inches.

Permeability of this Galt soil is slow. Available water capacity is low to moderate. Effective rooting depth is 20 to 40 inches. Runoff is very slow, and the hazard of water erosion is slight. This soil is subject to occasional long periods of flooding in December to April.

5. Live Oak Variant-Galt Variant complex, flooded. This map unit is on floodplains. Slope is between 0 and 5 percent. Areas of this map unit are cut by channels of abandoned streams and are marked by higher depositional bars made during flooding. The native vegetation is mainly annual grasses and

tules. Elevation is between 20 and 50 feet. The average annual precipitation is between 14 and 17 inches, the average annual air temperature is between 60 and 64 degrees F, and the average frost-free period is between 260 and 280 days.

This unit is 45 percent Live Oak Variant and 40 percent Galt Variant. Live Oak Variant is on convex depositional mounds and Galt Variant is in concave channels and inner mounds. Some areas have been leveled for rice culture. The components of this unit are so intricately intermingled that it was not practical to map them separately at the scale used.

The Live Oak Variant soil is deep and moderately well drained. It formed in alluvium derived dominantly from mixed sources. Typically, the surface layer is light brownish gray loam 6 inches thick. The subsoil is pale brown loam 48 inches thick. The next layer is a brown hardpan 9 inches thick. The underlying material from a depth of 63 to 73 inches or more is pale brown very fine sandy loam. In some areas the surface layer is less than 6 inches or absent due to leveling. Depth to hardpan ranges from 40 to 60 inches.

Permeability of the Live Oak Variant soil is moderate. Available water capacity is moderate to high. Effective rooting depth is 40 to 60 inches. Runoff is slow, and the hazard of water erosion is slight. The soil is wet between a depth of 48 and 60 inches in December through April. This soil is subject to frequent long periods of flooding in December through April.

The Galt Variant soil is moderately deep and somewhat poorly drained. It formed in alluvium derived dominantly from mixed sources. Typically, the surface layer is light brownish gray and pale brown clay loam 13 inches thick. The subsoil is light yellowish brown and very pale brown clay loam 8 inches thick. The next layer is a white strongly cemented hardpan 1 inch thick. The next layer is a very pale brown loam 3 inches thick. The next layer is white strongly cemented hardpan 1 inch thick. Siltstone is at a depth of 26 inches. In some areas, the surface layer is clay and in some areas, the surface layer is 20 to 30 inches thick due to leveling. Depth to hardpan ranges from 20 to 40 inches.

Permeability of the Galt Variant soil is moderately slow. Available water capacity is low to moderate. Effective rooting depth is 20 to 40 inches. Runoff is very slow, and the hazard of water erosion is slight. A perched wet zone is between 18 and 36 inches in December through April. This soil is subject to frequent long periods of flooding in December through April.

6. <u>Olashes sandy loam, flooded, 0 to 2 percent slopes</u>. This very deep, well drained soil is on alluvial fans. It formed in alluvium derived dominantly from mixed sources including volcanic ash. Elevation is between 45 and 75 feet. The average annual precipitation is between 16 and 19 inches, the average annual air temperature is between 58 and 62 degrees F, and the average frost-free period is between 250 and 270 days.

Typically, the surface layer is pale brown sandy loam about 4 inches thick. The subsoil is pale brown and light yellowish brown sandy clay loam

about 48 inches thick. The underlying material to a depth of 60 inches or more is yellowish brown sand.

Permeability of this Olashes soil is moderately slow to a depth of 52 inches and rapid below this depth. Available water capacity is high. Effective rooting depth is 60 inches or more. Runoff is very slow and the hazard of water erosion is slight. The soil is subject to frequent long periods of flooding in December through April.

7. Palls-Stohlman stony sandy loams, 9 to 30 percent slopes. This map unit is on hills. The native vegetation is mainly annual grasses and forbes. Elevation is between 75 and 1500 feet. The average annual precipitation is between 16 and 18 inches, the average annual air temperature is between 60 and 62 degrees F, and the average frost-free period is between 250 and 270 days.

This unit is 40 percent Palls and 35 Stohlman. Palls soil is on concave hillsides and Stohlman soil is on convex hillsides and on ridgetops. The components of this unit are so intricately intermingled that it was not practical to map them separately at the scale used.

The Palls soil is moderately deep and well drained. It formed in residuum derived dominantly from andesite and andesitic lahar. Typically, the surface is covered with 3 to 15 percent stones. The surface layer is brown and light brownish gray stony sandy loam about 8 inches thick. The subsoil is light brownish gray and pale brown gravelly sandy loam about 23 inches thick. Hard andesitic lahar is at a depth of 31 inches. Depth to bedrock ranges from 20 to 40 inches.

Permeability of the Palls soil is moderately rapid. Available water capacity is low to very low. Effective rooting depth is 20 to 40 inches. Runoff is rapid and the hazard of water erosion is moderate to high.

The Stohlman soil is shallow and well drained. It formed in residuum derived dominantly from andesite and andesitic lahar. Typically, the surface is covered with 3 to 15 percent stones. The surface layer is light brownish gray stony sandy loam about 7 inches thick. The subsoil is pale brown gravelly sandy loam about 9 inches thick. Hard andesitic lahar is at a depth of 16 inches. Depth to bedrock ranges from 10 to 20 inches.

Permeability of the Stohlman soil is moderately rapid. Available water capacity is very low. Effective rooting depth is 10 to 20 inches. Runoff is rapid and the hazard of water erosion is moderate to high.

This map unit is in capability subclass VIs (18), nonirrigated.

8. Olashes sandy loam, 0 to 2 percent slopes. This very deep, well drained soil is on alluvial fans. It formed in alluvium derived dominantly from mixed sources including volcanic ash. Elevation is between 45 and 750 feet. The average annual precipitation is between 16 and 19 inches, the average annual air temperature is between 58 and 62 degrees F, and the average frost-free period is between 250 and 270 days.

Typically, the surface layer is pale brown sandy loam about 4 inches thick. The subsoil is pale brown and light yellowish brown sandy clay loam about 48 inches thick. The underlying material to a depth of 60 inches or more is yellowish brown sand.

Permeability of this Olashes soil is moderately slow to a depth of 52 inches and rapid below this depth. Available water capacity is high. Effective rooting depth is 60 inches or more. Runoff is very slow and the hazard of water erosion is slight.

9. Shanghai silt loam, wet, 0 to 2 percent slopes. This very deep, somewhat poorly drained soil is on flood plains. It formed in alluvium derived dominantly from mixed sources. Elevation is between 20 and 80 feet. The average annual precipitation is between 17 and 20 inches, the average annual air temperature is between 60 and 64 degrees F, and the average frost-free season is between 260 and 280 days.

Typically, the surface layer is light yellowish brown silt loam about 8 inches thick. The underlying material to a depth of 60 inches or more is stratified light yellowish brown and very pale brown silt loam, very fine sandy loam and very pale brown and brown silty clay loam.

Permeability of this Shanghai soil is moderate. Available water capacity is high to very high. Effective rooting depth is 60 inches or more. A seasonal high water table is at a depth of 30 to 60 inches in December through April and at a depth of 48 to 60 inches in May through November. Runoff is very slow, and the hazard of water erosion is moderate. This soil is subject to frequent long periods of flooding from December through April.

10. Columbia fine sandy loam, frequently flooded, 0 to 2 percent slopes. This very deep, somewhat poorly drained soil is on flood plains. It formed in alluvium derived dominantly from mixed sources. Native vegetation is mainly trees with dense brush understory. Elevation is between 20 and 80 feet. The average annual precipitation is between 17 and 20 inches, the average annual air temperature is between 60 and 64 degrees F, and the average frost-free season is between 260 and 280 days.

Typically, the surface layer is pale brown and brown fine sandy loam about 14 inches thick. The underlying material to a depth of 60 inches or more is stratified pale brown and light yellowish brown fine sandy loam and light yellowish brown very fine sandy loam. In some areas, the surface layer is sandy loam or silt loam.

Permeability of this Columbia soil is moderately rapid. Available water capacity is moderate. Effective rooting depth is 60 inches or more. A seasonal high water table is at a depth of 36 to 60 inches in December through April. Runoff is very slow, and the hazard of water erosion is severe. This soil is subject to frequent long periods of flooding from December through April.

APPENDIX B

Table B-1. Plants found within sampling areas of Butte Sink, Sutter County, California. Four to six character species code and frequency of occurrence index numbers (Reed 1986) listed in right hand columns.

Species	Code	Index Number
Abutilon theophrasti	ABTH	5[a]
Acer negundo	ACNE2	2
Agropyron repens	AGRE	4
Aira caryophyllea	AICA	5[a]
Alopecurus howellii	ALHO3	2
Ammania coccinea	AMCO	1
Amsinckia intermedia	AMIN	5[a]
Ambrosia psilostachya	AMPS	3
Anthemis cotula	ANCO	4
Arenaria californica	ARCA1	5[a]
Aristolochia californica	ARCA2	5
Artemisia douglasiana	ARDO3	2
Aster exilis	ASEX	2[a]
Astragalus gambelianus	ASGA	5[a]
Avena fatua	AVFA	5[a]
Baccharis pilularis	BAPI	5
Bergia texana	BETE	1
Bidens frondosa	BIFR	2
Boisduvalia densiflora	BODE	2
Bromus diandrus	BRDI	5[a]
Brassica geniculata	BRGE	5[a]
Bromus mollis	BRMO	5[a]
Bromus tectorum	BRTE	5[a]

(Continued)

Table B-1. (Continued)

Species	Code	Index Number
Bromus sp.	BRUN	5[a]
Carex barbarae	CABA4	2
Capsella bursa-pastoris	CABU2	3
Cardaria draba	CADR	5[a]
Carex sp.	CASP	3[a]
Carex teneraeformis	CATE	5[a]
Cephalanthus occidentalis var. *californicus*	CEOC2	1
Centaurea solstitialis	CESO	5[a]
Chenopodium album	CHAL7	3
Chenopodium ambrosioides	CHAM	3
Chorogalum angustifolium	CHAN	5[a]
Chorizanthe membranacea	CHME	5[a]
Cirsium arvense	CIAR4	4
Cichorium intybus	CIIN	5[a]
Clematis ligusticifolia	CLLI2	3
Convolvulus arvensis	COAR	5[a]
Crypsis niliaca	CRNI3	1
Cuscuta indecora	CUIN	3
Cynodon dactylon	CYDA	3
Cyperus erythrorhizos	CYER2	1
Cyperus esculentus	CYES	2
Descurainia sophia	DESO	5[a]
Distichlis spicata	DISP	2
Echinochloa crusgalli	ECCR	2
Eleocharis coloradoensis	ELCO6	1
Eleocharis palustris	ELPA3	1
Elymus triticoides	ELTR3	3
Epilobium adenocaulon	EPAD	3[a]
Erodium botrys	ERBO	5[a]

(Continued)

Table B-1. (Continued)

Species	Code	Index Number
Eragrostis orcuttiana	EROR	4[a]
Eremocarpus setigerus	ERSE	5[a]
Eryngium vaseyi	ERVA5	2
Euphorbia ocellata	EUOC	5[a]
Festuca megalura	FEME	5[a]
Fraxinus latifolia	FRLA	2
Grindelia camporum	GRCA	4
Hemizonia fitchii	HEFI	5[a]
Helenium puberulum	HEPU	2
Heleochloa schoenoides	HESC	1[a]
Hibiscus californicus	HICA	1[a]
Hordeum depressum	HODE	3[a]
Hordeum leporinum	HOLE	5[a]
Hypochoeris radicata	HYRA	5[a]
Juncus bufonius	JUBU	2
Juncus effusus	JUEF	1
Juglans hindsii	JUHI	3
Kickxia elatine	KIEL	5[a]
Lathyrus jepsonii ssp. _californicus_	LAJE	3[a]
Lactuca saligna	LASA	5
Lactuca serriola	LASE	3
Leptochloa fascicularis	LEFA	1
Lepidium nitidum	LENI	5
Lippia nodiflora	LINO	3[a]
Lotus corniculatus	LOCO6	3
Lomatium dissectum	LODI	5[a]
Lolium multiflorum	LOMU	4[a]
Lolium perenne	LOPE	4
Lotus purshianus	LOPU	3[a]

(Continued)

Table B-1. (Continued)

Species	Code	Index Number
Lotus strigosus	LOST	5[a]
Lupinus bicolor	LUBI	5[a]
Lycopus americanus	LYAM	1
Lythrum californicum	LYCA4	1
Maclura pomifera	MAPO	5[a]
Malva nicaeensis	MANI	5[a]
Melilotus albus	MEAL	4
Medicago hispida	MEHI	3[a]
Mentha pulegium	MEPU	1
Myosurus minimus	MYMI	2
Navarretia squarrosa	NASQ	3[a]
Orthocarpus erianthus	ORER	3[a]
Paspalum dilatatum	PADI3	3
Paspalum distichum	PADI6	1
Phacelia ramosissima	PHRA	5[a]
Plantago major	PLMA2	2
Plagiobothrys nothofulvus	PLNO	3
Poa annua	POAN	2
Polygonum coccineum	POCO	1
Populus fremontii	POFR2	2
Polygonum lapathifolium	POLA4	1
Polypogon monspeliensis	POMO5	2
Poa pratensis	POPR	4
Psilocarphus brevissimus	PSBR	1
Quercus lobata	QULO	4
Raphanus sativus	RASA	5[a]
Rhus diversiloba	RHDI	4[a]
Rorippa curvisiliqua	ROCU	1
Rosa californica	ROCA2	3
Rumex crispus	RUCR	2

(Continued)

Table B-1. (Concluded)

Species	Code	Index Number
Rubus ursinus	RUUR	3[a]
Rubus vitifolius	RUVI	3
Salix gooddingii	SAGO	1
Salix lasiolepis	SALA	1[a]
Sambucus mexicana	SAME	3
Scirpus acutus	SCAC	1
Scirpus robustus	SCRO	1
Silene gallica	SIGA	5[a]
Sorghum halepense	SOHA	4
Solanum nodiflorum	SONO	3[a]
Solidago occidentalis	SOOC	3[a]
Spergula arvensis	SPAR	5[a]
Stachys rigida	STRI	2
Tillaea erecta	TIER	5[a]
Trifolium ciliolatum	TRCI	3[a]
Trifolium depauperatum	TRDE	3[a]
Trifolium gracilentum	TRGR	3[a]
Trichostema lanceolatum	TRLA	5[a]
Typha angustifolia	TYAN	1
Veronica peregrina	VEPE	2
Vitis californica	VICA5	2
Xanthium strumarium	XAST	3

[a]Taxa not included on Reed's (1986) list and indexes assigned based on the experience of principle investigator.

[b]Ecological index value modified from that of Reed (1986).

APPENDIX C

FREQUENCY TABLES

Table C-1. Frequency of occurrence of species found on 40 replications of Palls-Stohlman soil, Butte Sink, California.

Species	Frequency	Percent	Cumulative Frequency	Cumulative Percent
BRMO	39	12.6	39	12.6
ERBO	37	11.9	76	24.5
FEME	37	11.9	113	36.4
CHAN	29	9.4	142	45.8
TRDE	26	8.4	168	54.2
NASQ	17	5.5	185	59.7
ORER	17	5.5	202	65.2
TRGR	17	5.5	219	70.7
AICA	16	5.2	235	75.9
TRLA	13	4.2	248	80.1
HYRA	12	3.9	260	84.0
EUOC	8	2.6	268	86.6
BRDI	7	2.3	275	88.9
BRTE	6	1.9	281	90.8
LUBI	6	1.9	287	92.7
HODE	4	1.3	291	94.0
AVFA	3	1.0	294	95.0
ERSE	3	1.0	297	96.0
PHRA	3	1.0	300	97.0
SIGA	3	1.0	303	98.0
ASGA	1	0.3	304	98.3
CHME	1	0.3	305	98.6
HEFI	1	0.3	306	98.9
LENI	1	0.3	307	99.2
LOST	1	0.3	308	99.5
TIER	1	0.3	309	99.8
TRCI	1	0.3	310	100.0

Table C-2. Frequency of occurrence of species found on 40 replications of Columbia fine sandy loam soil, Butte Sink, California.

Species	Frequency	Percent	Cumulative Frequency	Cumulative Percent
LOPU	22	9.9	22	9.9
AGRE	20	9.0	42	18.9
MEAL	16	7.2	58	26.1
SOHA	16	7.2	74	33.3
CYES	14	6.3	88	39.6
SOOC	14	6.3	102	45.9
VEPE	14	6.3	116	52.2
BODE	12	5.4	128	57.6
ANCO	11	5.0	139	62.6
XAST	11	5.0	150	67.6
CADR	8	3.6	158	71.2
LINO	8	3.6	166	74.8
CHAL-7	6	2.7	172	77.5
POCO	6	2.7	178	80.2
RUCR	6	2.7	184	82.9
POFR-2	5	2.3	189	85.2
POMO-5	5	2.3	194	87.5
CYDA	4	1.8	198	89.3
CHAM	3	1.4	201	90.7
HEFI	3	1.4	204	92.1
HODE	3	1.4	207	93.5
ROCU	3	1.4	210	94.9
ARDO-3	2	0.9	212	95.8
HESC	2	0.9	214	96.7
SAGO	2	0.9	216	97.6
BRGE	1	0.5	217	98.1
JUBU	1	0.5	218	98.6
KIEL	1	0.5	219	99.1
MYMI	1	0.5	220	99.6
PLMA-2	1	0.5	221	100.4
PLNO	1	0.5	222	100.9

Table C-3. Frequency of occurrence of species found on 20 replications of Clear Lake clay soil (flooded old field), Butte Sink, California.

Species	Frequency	Percent	Cumulative Frequency	Cumulative Percent
XAST	14	13.6	14	13.6
ELPA-3	12	11.7	26	25.3
CYES	11	10.7	37	36.0
LINO	11	10.7	48	46.7
SCAC	11	10.7	59	57.4
RUCR	10	9.7	69	67.1
CYDA	6	5.8	75	72.9
ARDO-3	3	2.9	78	75.8
BIFR	3	2.9	81	78.7
CHAL	3	2.9	84	81.6
CYER-2	3	2.9	87	84.5
HEPU	2	1.9	89	86.4
POCO	2	1.9	91	88.3
SOOC	2	1.9	93	90.2
AMPS	1	1.0	94	91.2
ASEX	1	1.0	95	92.2
CABA-4	1	1.0	96	93.2
CHAM	1	1.0	97	94.2
COAR	1	1.0	98	95.2
LOPE	1	1.0	99	96.2
MEAL	1	1.0	100	97.2
PADI-6	1	1.0	101	98.2
POMO-5	1	1.0	102	99.2
QULO	1	1.0	103	100.0

Table C-4. Frequency of occurrence of species found on 20 replications of Clear Lake clay (tule marsh), Butte Sink, California.

Species	Frequency	Percent	Cumulative Frequency	Cumulative Percent
XAST	20	17.4	20	17.4
ELPA-3	10	8.7	30	26.1
SCAC	10	8.7	40	34.8
RUCR	9	7.8	49	42.6
CYES	8	7.0	57	49.6
POCO	8	7.0	65	56.6
ARDO-3	6	5.2	71	61.8
PADI-3	6	5.2	77	67.0
BIFR	5	4.3	82	71.3
CYDA	5	4.3	87	75.6
LINO	5	4.3	92	79.9
ASEX	3	2.6	95	82.5
CADR	3	2.6	98	85.1
CHAL-7	2	1.7	100	86.8
ECCR	2	1.7	102	88.5
LOMU	2	1.7	104	90.2
SOOC	2	1.7	106	91.9
BODE	1	0.9	107	92.8
CHAM	1	0.9	108	93.7
CIAR	1	0.9	109	94.6
HODE	1	0.9	110	95.5
LYAM	1	0.9	111	96.4
PLMA-2	1	0.9	112	97.3
POMO-5	1	0.9	113	98.2
STRI	1	0.9	114	99.1
VEPE	1	0.9	115	100.0

Table C-5. Frequency of occurrence of species found on 20 replications of Clear Lake clay soil (siltstone substratum - depressions between mounds), Butte Sink, California.

Species	Frequency	Percent	Cumulative Frequency	Cumulative Percent
		Pond bottoms		
CRNI-3	20	16.9	20	16.9
AMCO	19	16.1	39	33.0
HESC	19	16.1	59	49.1
BETE	18	15.3	76	64.4
CYDA	16	13.6	92	78.0
ELCO-6	16	13.6	108	91.6
ELPA-3	6	5.1	114	96.7
ECCR	2	1.7	116	98.4
LEFA	1	0.8	117	99.2
SCRO	1	0.8	118	100.0
		Drainage Channels		
MEAL	19	15.6	19	15.6
CRNI-3	17	13.9	36	29.5
XAST	15	12.3	51	41.8
CYDA	12	9.8	63	51.6
MEHI	9	7.4	72	59.0
POCO	9	7.4	81	66.4
HESC	87	6.6	89	73.0
LOCO-6	8	6.6	97	79.6
LOPU	8	6.6	105	86.2
LEFA	5	4.1	110	90.3
EOCR	4	3.3	114	93.6
LYCA-4	3	2.5	117	96.1
ABTH	2	1.6	119	97.7
BODE	1	0.8	120	98.5
ELCO-6	1	0.8	121	99.3
SALA	1	0.8	122	100.0

Table C-6. Frequency of occurrence of species found on 20 replications of Clear Lake clay soil (siltstone substratum - raised areas separating depressions), Butte Sink, California.

Species	Frequency	Percent	Cumulative Frequency	Cumulative Percent
ELTR-3	23	22.3	23	22.3
LOPE	14	13.6	37	35.9
RUCR	14	13.6	51	49.5
COAR	7	6.8	58	56.3
CYDA	6	5.8	64	62.1
ARDO-3	4	3.9	68	66.0
BRGE	4	3.9	72	69.9
HOLE	4	3.9	76	73.8
AVFA	3	2.9	79	76.7
AMPS	2	1.9	81	78.6
BRTE	2	1.9	83	80.5
CABA-4	2	1.9	85	82.4
CESO	2	1.9	87	84.3
CLLI-2	2	1.9	89	86.2
LINO	2	1.9	91	88.1
RHDI	2	1.9	93	90.0
SOHA	2	1.9	95	91.9
ARCA	1	1.0	96	92.9
BRDI	1	1.0	97	93.9
CADR	1	1.0	98	94.9
CIIN	1	1.0	99	95.9
LAJE	1	1.0	100	96.9
LASE	1	1.0	101	97.9
POAN	1	1.0	102	98.9
RUUR	1	1.0	103	100.0

Table C-7. Frequency of occurrence of species found on 40 replications of Shanghai silt loam soil, Butte Sink, California.

Species	Frequency	Percent	Cumulative Frequency	Cumulative Percent
SOHA	9	28.1	9	28.1
ELTR-3	7	21.9	16	50.0
RUCR	4	12.5	20	62.5
RUUR	3	9.4	23	71.9
ARDO-3	2	6.3	25	78.2
BRGE	1	3.1	26	81.3
BRTE	1	3.1	27	84.4
JUHI	1	3.1	28	87.5
LOPE	1	3.1	29	90.6
RHDI	1	3.1	30	93.7
VICA-5	1	3.1	31	96.8
XAST	1	3.1	32	100.0

Table C-8. Frequency of occurrence of species found on 40 replications of Galt clay soil, Butte Sink, California.

Species	Frequency	Percent	Cumulative Frequency	Cumulative Percent
CYDA	32	13.1	32	13.1
RUCR	30	12.3	62	25.4
LOCO-6	28	11.5	90	36.9
XAST	20	8.2	110	45.1
JUEF	17	7.0	127	52.1
COAR	16	6.6	143	58.7
CASP	15	6.1	158	64.8
LOPE	12	4.9	170	69.7
LASE	11	4.5	181	74.2
HODE	7	2.9	188	77.1
LOMU	7	2.9	195	80.0
DISP	6	2.5	201	82.5
GRCA	6	2.5	207	85.0
MEAL	6	2.5	213	87.5
CHAL-7	5	2.0	218	89.5
ELPA-3	4	1.6	222	91.1
MANI	4	1.6	226	92.7
POCO	3	1.2	229	93.9
POMO-5	3	1.2	232	95.1
HESC	2	0.8	234	95.9
LASA	2	0.8	236	96.7
STRI	2	0.8	238	97.5
BRUN	1	0.4	239	97.9
CESO	1	0.4	240	98.3
LEFA	1	0.4	241	98.7
LYCA-4	1	0.4	242	99.1
POPR	1	0.4	243	99.5
SCAC	1	0.4	244	100.0

Table C-9. Frequency of occurrence of species found on 40 replications of Olashes sandy loam soil, Butte Sink, California.

Species	Frequency	Percent	Cumulative Frequency	Cumulative Percent
BRMO	40	17.1	40	17.1
AVFA	38	16.2	78	33.3
ERBO	33	14.1	111	47.4
FEME	26	11.1	137	58.5
HOLE	24	10.3	161	68.8
LOPU	21	9.0	182	77.8
AMIN	12	5.1	194	82.96
LUBI	11	4.7	205	87.6
CHAN	6	2.6	211	90.2
COAR	5	2.1	216	92.3
ERSE	5	2.1	221	94.4
LOPE	5	2.1	226	96.5
MEHI	5	2.1	231	98.6
LOMU	2	0.9	233	99.5
HYRA	1	0.4	234	100.0

Table C-10. Frequency of occurrence of species found on 40 replications of Olashes sandy loam soil (flooded), Butte Sink, California.

Species	Frequency	Percent	Cumulative Frequency	Cumulative Percent
LOMU	39	20.2	39	20.2
MEHI	36	18.7	75	38.9
COAR	31	16.1	106	55.0
HODE	26	13.5	132	68.5
ANCO	15	7.8	147	76.3
CESO	9	4.7	156	81.0
POAN	8	4.1	164	85.1
LASE	7	3.6	171	85.1
ERBO	6	3.1	177	91.8
RUCR	6	3.1	183	94.9
HEFI	3	4.6	186	96.5
LODI	2	1.0	188	97.5
BRMO	1	0.5	189	98.0
CABU-2	1	0.5	190	98.5
DESO	1	0.5	191	99.0
LUBI	1	0.5	192	99.5
RASA	1	0.5	193	100.0

Table C-11. Frequency of occurrence of species found on 20 replications of Live Oak Variant-Galt Variant soil (uplands), Butte Sink, California.

Species	Frequency	Percent	Cumulative Frequency	Cumulative Percent
CATE	20	16.1	20	16.1
LASE	20	16.1	40	32.2
COAR	19	15.3	59	47.5
LOPE	18	14.5	77	62.0
CYDA	14	11.3	91	73.3
RUCR	11	8.9	102	82.2
AMPS	8	6.4	110	88.6
LOCO-6	5	4.0	115	92.6
LASA	3	2.4	118	95.0
MEAL	21	1.6	120	96.6
POPR	2	1.6	122	98.2
CASP	1	0.8	123	99.0
STRI	1	0.8	124	100.0

Table C-12. Frequency of occurrence of species found on 20 replications of Live Oak Variant-Galt Variant soil (swales), Butte Sink, California.

Species	Frequency	Percent	Cumulative Frequency	Cumulative Percent
POMO-5	19	19.6	19	19.6
GRCA	14	14.4	33	34.0
CYDA	10	10.3	43	44.3
ELPA-3	9	9.3	52	53.6
XAST	7	7.2	59	60.8
LYCA-4	5	5.1	64	65.9
COAR	3	3.1	67	69.0
ERSE	3	3.1	70	72.1
LOCO-6	3	3.1	73	75.2
MEAL	3	3.1	76	78.3
RUCR	3	3.1	79	81.4
BODE	2	2.1	81	83.5
ERVA-5	2	2.1	83	85.6
LASE	2	2.1	85	87.7
PLMA-2	2	2.1	87	89.8
POCO	2	2.1	89	91.9
POpR	2	2.1	91	94.0
ARCA	1	1.0	92	95.0
HODE	1	1.0	93	96.0
PLNO	1	1.0	94	97.0
PSBR	1	1.0	95	98.0
TRGR	1	1.0	96	99.0
VEPE	1	1.0	97	100.0

Table C-13. Frequency of occurrence of species found on 40 replications of Capay silty clay soil, Butte Sink, California.

Species	Frequency	Percent	Cumulative Frequency	Cumulative Percent
XAST	31	23.8	31	23.8
CYDA	20	15.4	51	39.2
SCAC	19	14.6	70	53.8
PADI-3	14	10.8	84	64.6
ECCR	10	7.7	94	72.3
CEOC-2	5	3.8	99	76.1
CYER-2	5	3.8	104	79.9
POLA-4	4	3.1	108	83.0
ELPA-3	3	2.3	111	85.3
HICA	3	2.3	114	87.6
MEAL	3	2.3	117	89.9
CHAL-7	2	1.5	119	91.4
SAGO	2	1.5	121	92.9
ALHO-3	1	0.8	122	93.7
AMCO	1	0.8	123	94.5
EROR	1	0.8	124	95.3
LINO	1	0.8	125	96.1
LYAM	1	0.8	126	96.9
POCO	1	0.8	127	97.7
SONO	1	0.8	128	98.5
SPAR	1	0.8	129	99.3
TYAN	1	0.8	130	100.0

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15. Supplementary Notes

16. Abstract (Limit: 200 words)

As part of a national study, vegetation associated with known hydric and nonhydric soil series was sampled in the vicinity of Butte Sink in the Sacramento Valley of northern California. Weighted averages, presence/absence averages, and Michener averages were calculated for vegetation in each soil series or vegetation type within soil series based on importance values and ecological indices assigned by the National Wetland Plant List. In all cases, currently flooded hydric soils were designated as wetlands based on vegetation. Three soils originally classified as hydric but now surrounded by levees and used largely for agriculture supported nonhydric herbaceous vegetation. More long-lived woody strata on Shanghai silt loamy reflected the initially more hydric conditions encountered prior to the construction of levees. Vegetational disturbance associated with the management of Butte Sink wetlands by duck club owners appeared to increase the likelihood that dominance of one or a few early successional plant species may be expressed. In these cases, the weighted average method appears to be the most accurate indicator of hydric status.

17. Document Analysis a. Descriptors

Wetland soils
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Wetland ecology
Wetland ecosystems

b. Identifiers/Open-Ended Terms

Butte Sink wetland

c. COSATI Field/Group

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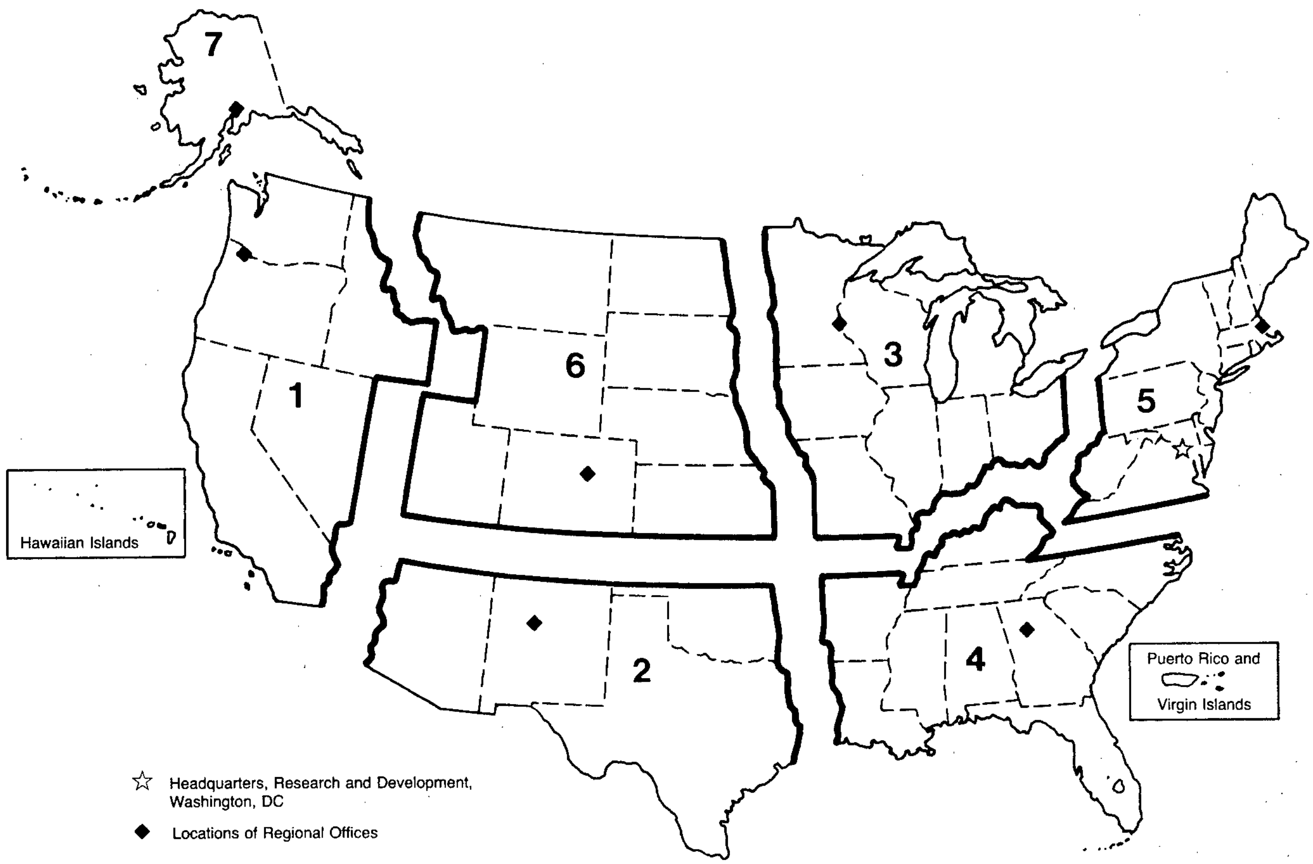

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